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# Green Granary Temperature Control System Modeling and Simulation

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**Abstract**

As an important link of food production and distribution process, Granary's temperature control performance seriously affects the food quality and storage costs. Based on the analysis of granary components, granary temperature control model is established. The simulation results show the validity of established model.



***Keywords:*** *Green* granary, temperature control, thermodynamics, storage cost.

## 1. Introduction

As the basic subsistence of human survival and development, grain is beneficial to people's livelihood strategy goods and materials, and has special status and function in people's lives and the national economy development. As an important link of food production and distribution process, granary is the important foundation for ensuring food safety[1]. During the storage process, grain both inside and outside would be easily dewing due to changes of external temperature and interior biological components of life activity. The granary temperature imbalance control will lead to grain mildew and infestation moth, thus cause huge loss [2 ]. Therefore, a granary temperature control system is very necessary.

Low temperature is one of the most common green grain storage technologies. In store grain ecosystem, abiotic factors ( such as temperature ) are closely related to biological factors. In general, grain insect grows slowly below 20˚C, and requires around 60 days to complete a generation growth. While insect would grow more slowly below15˚C, and could hardly finish a generation. So, low temperature control can effectively prevent stored grain insects, suppress food breathing, delay grain quality deterioration, and reduce the chemical residue pollution [3]. Based on the theory of thermodynamics, the modeling of granary temperature control system is studied in this paper.

## 2. Green granary temperature control system analysis

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The granary, as independent building, has a height of about 10 meters. Because its roof has no shading and large area, using solar photovoltaic generation becomes feasible. It has great advantages to apply the photovoltaic roof power to grain storage with low temperature. On the one hand, solar panels on the roof has good heat insulation performance, so that the granary of their load is reduced. And on the other hand, impetus energy can be provided to granary storage by photovoltaic generation, in order to realize the granary grain storage at low temperature to provide the for development. Therefore, it is significant to study green granary.

A typical green granary temperature system includes four subsystem: outdoor temperature system, heater blower, photovoltaic system and granary, as shown in Fig.1. It can be seen from Fig.1 that, 1) Outdoor system transfers heat to granary system when outdoors temperature is high; 2) heater blower would start once the temperature of granary is on or below the setpoint and the granarysytem feedbacks the regulated signal to heater blower; 3) photovoltaic system would provide enough electricity to guarant the operation of heater blower.

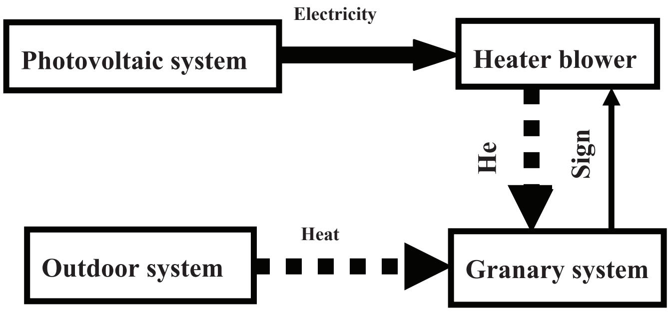


Figure 1 typical green granary temperature control system

## 3. Modeling of Green granary temperature control system

The operation of green granary temerature control system has been illustrationed in the Part II. Before modeling of temperature control system, mathematic expression of four subsystem should be described first.

(1) Outdoor system

Although the temperatue varies from day to day, and from place to place, Daily temperature variation can be described as:

$$T_{out} = T_o + T_i \sin(2\pi/(24\times 3600)) \quad (1)$$

Where, $T_{out}$ is the outdoor temperature at time $t$; $T_o$ is average outdoor temperature, and $T_i$ is maximum of temperature variation.

(2) Granary system

Granary system is the main part of the whole system. Its expression is as follows:

$$T_{in}(t+1) = \int [(T_{out}(t) - T_{in}(t))/R_{eq} + Q]/(M * C)dt \quad (2)$$

Where, $T_{in}$ is the input temperature of granary at time $t$; $R_{eq}$ is the equivalent thermal resistance; $Q$ is heating load or cooling load; $M$ is the mass of grain;$C$ is the specific heat capacityof grain.

(3) Heater blower

$$Q = sigh(T_{err})M_d E_a \quad (3)$$

Where, sigh($T_{err}$) stands for the operation mode of heater blower; $M_d$ is air flow rate; $E_a$ is enthalpy of air.

(4) Photovoltaic system

The I-V characteristic of photovoltaic system can be expressed as[4]:

$$I_{PV} = N_{pp}\left\{ I_L - I_0\left[\exp\left(\frac{\frac{U_{PV}}{N_s N_{ss}} + \frac{I_{PV}R_s}{N_{pp}}}{a}\right) - 1\right] - \frac{\frac{U_{PV}}{N_s N_{ss}} + \frac{I_{PV}R_s}{N_{pp}}}{R_{sh}}\right\} \tag{4}$$

$$P_{PV} = U_{PV} I_{PV}$$

Where, $U_{PV}$, $I_{PV}$, $P_{PV}$ are the output voltage, current and power of solar array,respectively; $N_s$ is the series number of single solar array; $Nss$ is series number of solar arrays; $Npp$ is parallel number of solar arrays; $I_L$, $I_o$, $\alpha$, $R_s$ and $R_{sh}$ are the light current, diode reverse saturation current, ideal factor, series resistance and shunt resistance, respectively.

Based on the description above, the simulation model of Green granary temperature control system is established using MATLAB/Simulink, as shown in Fig.2. It should be noted that we only investigate the sytem temperature performance in this paper, so we ignore the PV system in simulation model.

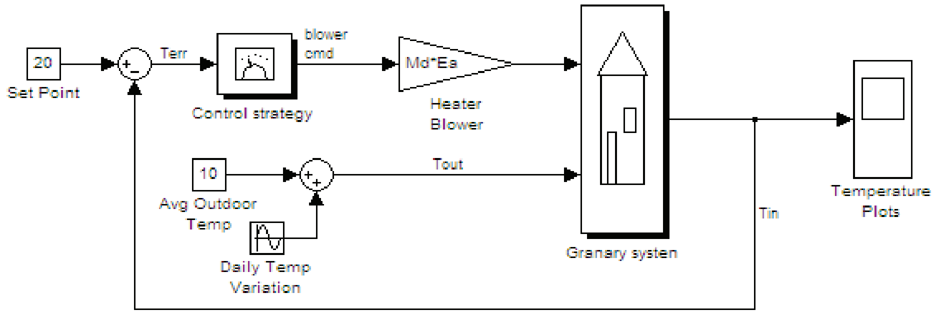


Figure 2 model of typical green granary temperature control system

## 4. Simulation and Analysis

In order to verify the validity of proposed model, a small granary system is taken as an example to do some simulations. Table 1 shows the main parameters of granary temperature control system during the simulation.

Table 1 Main simulation parameters of granary temperature control system

| | | |
|---|---|---|
| Granary geometry | Length | 60 m |
| | width | 40 m |
| | Height | 10 m |
| Enthalpy of air | | 311.4kJ/kg |
| Air flow rate | | 0.1 kg/sec |
| Initial indoor temperature | | 25˚C |
| Average outdoor temperature | | 15˚C |
| maximum of temperature variation | | 15˚C |
| Set temperature | | 20˚C |
| Density of Rice | | 2000kg/m$^3$ |

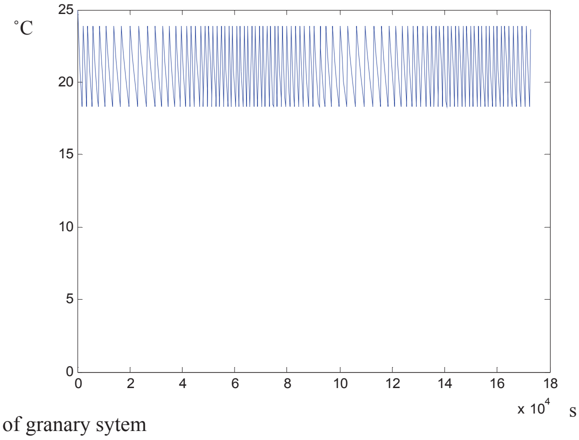


Figure 3 temperature variation of granary sytem

Fig.3 shows the temperature variation of granary system in one day.It is seen that, the average temperature system is about 20˚C.

In order to valuate the control performance, heat cost is adopted as an index. The heat cost of granary system during control is shown in Fig.4. It can be seen from Fig.4 that, the heat cost of granary is increasing during the control process ,and the total cost in one day is about 196 YUAN.

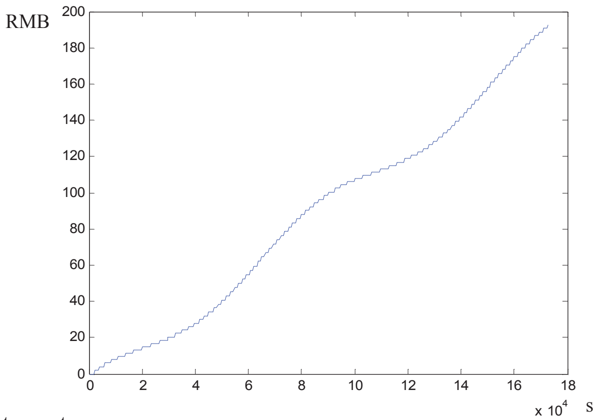


Figure 4 cost of granary temperature sytem

## 5. Summary

In the paper, the modeling and simulation of greengranary temperature control system is studied. Based on the mathematic expression analysis of four parts of granary components, granary temperature control model is established in MATLAB/Simulink . The simulation results show the validity of established model.

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